SAVANNAH RIVER SITE

321-M Fuel Fabrication Facility

Technology Post-Demonstration Fact Sheet
March 30, 1999

X-RAY K-EDGE HEAVY METAL DETECTION

Need Description

For thirty-five years, the 321-M Facility fabricated fuel assemblies for the SRS production reactors. The manufacturing process, combined with high ventilation flow rates, left dust, cuttings, and other forms of highly enriched uranium (HEU) in the building ventilation ducts and the process equipment enclosures. This material is not easily detected with conventional survey instruments because it emits only alpha particles and low energy gammas. The conventional method of measurement used a NaI portable detector which has a resolution of +100%, -50%. A more precise assay measurement was sought.

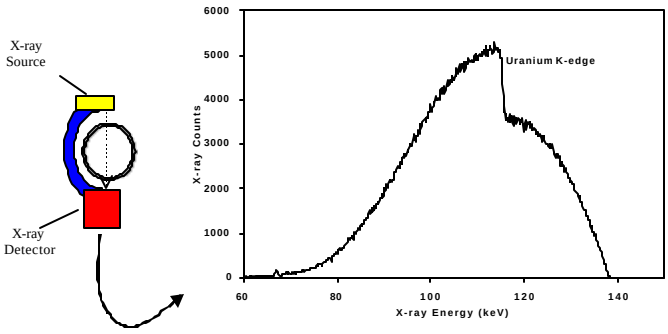

Figure 1. K-Edge Drop for Actual X-Ray Shot

Innovative Technology Description

The X-Ray, K-Edge Heavy Metal Detection System was designed and built by Ames Laboratory and the Center for Nondestructive Evaluation at Iowa State University.

The X-Ray, K-Edge System uses the characteristic absorption of x-rays in heavy metals. An x-ray beam is passed through unknown material. At an element-specific energy, corresponding to the binding energy of the K-shell electrons for that material, x-ray transmission is significantly reduced. An energy sensitive high purity germanium detector (HPGe) is used to analyze the transmitted beam. The energy at which the absorption occurs (known as the K-edge) determines the material; it is unique for each element. The magnitude of the intensity drop can be used to determine the amount of the material.

The measurement system contains three major subsystems: an x-ray generator, a detection subsystem, and a data acquisition subsystem. The x-ray tube and detection subsystem are mounted on a support frame that can be adjusted to accommodate the configuration of the inspected object. The support frame and its attached components is called the inspection head. The data acquisition subsystem contains a personal computer that controls the equipment and analyzes and displays the results.

There are two modes of detection: a wide angle, real-time x-ray imaging mode to ascertain physical distribution of holdup material and a narrow beam spectroscopic mode to quantify a given element.

Baseline Technology

The baseline technology for assaying ventilation ducts and process equipment enclosures is a collimated 2x2-inch NaI hand-held detector. This is a passive gamma measurement system with an advertised precision of +100%, -50%. This system provides a field of view of 45^0 about the axis of the detector.

Demonstration Description

The X-Ray, K-Edge System was used to measure the amount of HEU in the rooftop ventilation exhaust ducts for the Machining Room lathes. The technology will be compared with the NaI passive gamma technology on the basis of cost, speed, precision, ease of deployment, and quality of data.

After the initial setup and validation of the x-ray operation exclusion zone, wide-angle scans were performed to determine the relative distribution of the material and to establish the number and location of subsequent measurements. Narrow-beam measurements were then made to quantify the material and confirm the elemental makeup of the material.

Figure 2. Inspection Head on Ventilation Duct

Demonstration Summary

The Lathe Enclosures rooftop exhaust ducting, up to the HEPA filters, was assayed by the X-ray, K-Edge System. Sixty-six wide-angle images and sixty-six narrow beam spectroscopic shots were made during the 26.5 hours of x-ray operation time. Time expended to reposition the inspection head, perform calibration checks, perform safety interlock checks, perform alignment checks between the imaging unit and the HPGe detector, move the inspection head and vertical stand from one scaffolding platform to another, and find and resolve a few minor electrical problems was included in this total. Approximately 84 feet of ventilation duct was assayed.

The typical measurement cycle for this demonstration entailed two to eight images and spectroscopic shots per linear foot of ventilation duct. Each image looked at a 4" by 4" square. Since seams, bends, and duct diameter reductions yielded the highest HEU measurements, it was in these areas where the most images were taken. It took the X-ray, K-edge operators one to three minutes to acquire an image. A narrow beam measurement was then made to quantify any uranium present at that location.

In cases where there was no obvious indication of uranium, it could take up to ten minutes to achieve a 99% confidence level upper limit. When the images clearly showed the presence of uranium, three to six interrogative shots were made to verify the element and quantify the deposit. The larger the gram content of the deposit, the shorter the time necessary to get a precise reading. Larger deposits only required a one to two minute count time. When gram quantities of uranium were found, the precision was in the + or – 3% range. About one quarter of the 66 narrow beam measurements identified a significant amount of HEU. The other narrow beam measurements placed well-defined upper limits on the amount of uranium present in those areas.

Preliminary data evaluation indicates the X-ray, K-edge System is more precise than the baseline method and provides a quantifiable profile of uranium within the ventilation duct. The inability of the NaI detector to pinpoint the exact location of uranium within a container (like a ventilation duct) proved to be the baseline technology's most significant deficiency. Comprehensive performance and cost analyses are underway and will be reported via a DOE Office of Science and Technology Innovative Technology Summary Report (ITSR).

Planned improvements of the X-ray, K-edge System include using smaller detectors to make the inspection head more portable.

Benefits of the X-Ray, K-Edge Heavy Metal Detection System

- Provides a precise assay measurement
- Provides a quantifiable profile of the heavy metal holdup within a container
- Provides a real-time record of each image and narrow beam spectroscopic measurement
- Provides a non-destructive evaluation of containers with different geometries and with varying wall thicknesses

Future Applicability

The X-ray, K-edge System is best suited for environments where the container material or geometry is not well known or where the holdup material has an irregular distribution. When a holdup material profile is necessary to make work scope decisions, the X-ray, K-edge System is the technology of choice. Improvements to the X-ray, K-edge System will make it more portable and thereby reduce setup time between the x-ray shots.

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